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Abstract

Yuchanyan Cave in Daoxian County, Hunan Province (PRC), yielded fragmentary remains of two or more ceramic vessels, in addition to large amounts of ash, a rich animal bone assemblage, cobble and flake artifacts, bone tools and shell tools. The artifacts indicate that the cave was a Late Paleolithic foragers' camp. Here we report on the radiocarbon ages of the sediments based on analyses of charcoal and bone collagen. The best-preserved charcoal and bone samples were identified by prescreening in the field and laboratory. The dates range from around 13,800 years cal BP to 21,000 years cal BP. We show that the age of the ancient pottery ranges between 15,430 and 18,300 years cal BP. Charcoal and bone collagen samples located above and below one of the fragments all produced dates of around 18,000. These ceramic potsherds therefore provide some of the earliest evidence for pottery making in China.

\body**Introduction**

Numerous caves in the vast karstic landscape of the southern area of the Yangzi River basin of China are known to have been inhabited by hunter-gatherer groups during the Late Pleistocene and early Holocene. The generally good preservation of the cave deposits and the presence of rich archaeological assemblages, including stone, bone, and shell tools, have led to a large number of excavations since the 1980s. While similarly well-preserved Late Pleistocene cave sites are found in other regions of the world, the cave sites in this region of South China (as well as several sites in neighboring Japan and the Russian Far East) are unique due to the presence of ceramic vessels in their otherwise Late Paleolithic assemblages. Among the well-known sites in China from this period are Xianrendong and Diaotonghuan in Jiangxi Province (1-4), Miaoyan in Guangxi Province (5, 6), and Yuchanyan in Hunan Province (7). Previous studies of these sites have produced dates for this pottery ranging ca. 16,000-10,000 cal BP, (8-15), indicating that the world's first pottery was produced in East Asia. Many of these studies do not report a systematic analysis of the ages of the strata within the site, and in particular those containing the potsherds. Here we date the stratigraphic sequence deposited in Yuchanyan Cave, paying particular attention to the strata in close proximity to the potsherds.

Chinese Late Paleolithic sites such as Yuchanyan are rich in terrestrial and aquatic fauna, including deer, boar, birds, tortoises, fish, and various small mammals. Rice phytoliths and husks have been identified at Xianrendong, Diaotonghuan, and Yuchanyan, and several studies have attempted to differentiate wild and domestic species or to suggest an incipient stage of cultivation (4, 16, 17). Because of the presence of such plant remains and early pottery, these caves are often seen as the predecessors of the early Holocene open-air Neolithic villages found in the alluvial plain of the Yangzi river and its tributaries, such as the Pengtoushan and Bashidang sites, and other settlement sites of the Pengtoushan Culture (18, 19).

Paleoclimatic data for the region suggest similar trends to those reported globally (20). The last glacial maximum (LGM) ca. 23,000-18,000 cal BP led to lower temperatures and increased aridity, with average temperatures in the Yangzi basin ca. 4-5°C cooler than today (21). Deciduous trees were increasingly replaced by grasses (22, 23). The Terminal Pleistocene warming was interrupted by the Younger Dryas ca. 13,000-11,500 cal BP. Although the Younger Dryas is seen in other regions as a generally cold and dry period, in South China the main effect of the Younger Dryas was probably the sudden onset of greater seasonality.

Understanding the local impact of the Younger Dryas on the basin of the Yangzi River and in particular in the limestone region south of the main river channel is still not possible (20).

While there have been previous excavations of Late Pleistocene cave sites in the Yangzi Basin, the dating of these sites has been problematic. First, the complex deposition of interdigitating lenses of ashes, clays, and sometimes fine gravel requires systematic dating based on a series of radiocarbon determinations, and this has been lacking. Secondly, accurate and precise radiocarbon dating of these sites in the past has proven to be difficult. While excavators of the cave sites have cited the cause as contamination from calcium carbonate in the karstic environment of the cave (2), this problem actually may be related to the presence of large amounts of calcite in the archaeological matrix of the caves. This can indirectly result in poor charcoal preservation (24). Here we apply a pre-screening strategy for identifying the best-preserved bone collagen and charcoal samples. We then analyze 29 prescreened samples for radiocarbon contents. This results in a much clearer understanding of the chronology of Yuchanyan Cave and the age of the pottery found in this site, as compared to other Late Pleistocene caves in East Asia.

Excavations in Yuchanyan Cave

Yuchanyan Cave (N 25°30’, E 111°30’) is located in Daoxian County, ca. 450 km south of the main course of the Yangzi River (Fig. 1 inset). The cave is 12-15 m wide along its east-west axis and about 6-8 meters wide from north to south. The uppermost deposits were removed in historical time. The cave was first excavated in 1993 and 1995 by one of the authors (J.Y.), who uncovered two clusters of potsherds indicating the presence of two vessels. A piece of charcoal closely associated with the potsherds was dated to 16,700 – 15,850 cal BP and organic residue from the ceramic to 17,750 – 16,900 cal BP ((7, 16, 17, 25) see Table 1). The pottery was coarsely made, with thick, uneven walls up to 2 cm thick, and was fired at low temperatures. Infrared spectra indicate that the firing temperature was between 400 and 500ºC, with kaolinite being a major clay component (unpublished observation). Due to the crumbly state of the sherds, only one pot could be reconstructed. Its form features a round rim 31 cm in diameter and a pointed base—a type known in the Chinese literature as a *fu* cauldron. The vessel has a height of 29 cm. Both the interior and exterior surfaces were impressed, possibly with cordage (7).

The 1993 and 1995 excavations at Yuchanyan opened an area of 46 square meters, with an excavation grid subdivided into squares (Fig. 1). During the excavations in 2004-2005, we subdivided the large rectangular square T1 into 1 x1 m squares and added, along the baulk between T1 and T3, four 1 x1 m squares, T10-T13. These were subdivided into four quadrants of 50 x 50 cm (Fig.1). We also excavated a one meter square in T4 and cleaned all the sections in order to clarify the exposed stratigraphy. In addition to the radiocarbon dating reported here, we studied site formation processes using micromorphology and mineralogy. A taxonomic and taphonomic study of the fauna was also carried out ((26) submitted). The small collection of lithic artifacts recovered was recently recorded and found to reflect the same tool categories known from the first excavations, dominated by core-choppers and retouched flakes. A few bone and shell tools were reported previously (16).

Results

Cave Sediments

The bedrock of Yuchanyan cave slopes steeply from the east, where it is about 2.0 m below datum, to the west, where it is 3.2 m below datum. The cave can be roughly sub-divided into 3 main areas differentiated mainly by major rockfalls. The western area (mainly square T1) is composed of two major lithostratigraphic units: the uppermost intact unit is composed of ~ 80 cm of calcareous anthropogenic deposits resulting from numerous burning events. Specifically, they are stringers composed of white and light gray calcitic ash lenses, that in cases overlie discontinuous bands of red clay which are ~ 1 – 3 cm thick by ~ 30 – 50 cm long. The many ashes and red bands are compact and massive, with mm size aggregates of red clay (Figs. 2 and S1). Well bedded lenses with varying white and red colored fine-grained sediments are separated by brown colored sediments. The major mineral components of these sediments are calcite, quartz, and clay. The central area (squares T3 and T4) contains brown colored sediments, with fewer lenses. The sediments here are also composed mainly of calcite, quartz, and clay. The eastern part of the cave (square T5) contains massive brown sediments with almost no color differences, and stratification is not clearly visible. These sediments are also dominated by calcite, quartz, and clay. Micromorphological analyses of the sediments clearly show that the calcite is mainly composed of wood ash that has been weakly cemented. The ash is remarkably well preserved, and in many samples rectangular pseudomorphs of wood-derived calcium oxalate crystals can be observed. Furthermore, much of the red clay (Fig. S2) was purposefully brought into the cave, as there are no possible geological means for clay to accumulate as lenses within the cave. In fact, the massive lenses (e.g., the one shown in Fig.S1) are constructed surfaces and are virtually identical to similar features from the Paleoindian site of Dust Cave in Alabama (27). Infrared spectra of the red lenses shows that some of them were exposed to temperatures between 400 and 500ºC based on the absence of absorption peaks around 3600cm^{-1}. For kaolinite, one of the major clay components in these sediments, these peaks disappear when the clay is exposed to temperatures above 400ºC (28). Note, too, that the clay component extracted from white lenses also often showed these characteristics. Thus, the exposure to elevated temperatures was probably part of the normal use of fires and was not associated with the production of ceramics.

Prescreening of Bone and Charcoal Samples for Radiocarbon Analysis

The distribution of bones was more or less uniform in all areas of the cave. In contrast, the charcoal was much less abundant in the western T5 square, especially in the deeper part of the section. Of the samples collected from throughout the cave, about 35% of the bones and about 45% of the charcoal were suitable for dating. For both bone and charcoal, the proportions of dateable samples in squares T4 and T5 were much less than for the squares in the eastern parts of the cave. The preservation conditions are clearly much better in the western part of the cave. The results of the pre-screening procedure are presented in Table 2.

Seventy-five charcoal samples were selected, pre-screened, and pretreated. After the pre-treatment, 21 samples were found to contain clay based on their infrared spectra (strong absorptions at 1033cm^{-1} together with absorptions at 535 and 472cm^{-1}). As clay is a potential carbon carrier and therefore a possible contaminant, these samples were excluded. Furthermore, an additional 8 samples dissolved completely during the procedure. The infrared spectra of the remaining samples showed only charcoal (peaks from 1718 to 1595 cm^{-1}) and thus could potentially be used for ^{14}C analysis. Twenty of these samples that contained relatively large amounts of material were also analyzed by Raman spectroscopy. The average fluorescence intensity after the first and last HCl steps decreased in all the samples except for 4 samples (YAS 237d, 540, 559 and T1E 6), indicating that most of the humic acid was removed during the acid-alkali-acid (AAA) treatment. These 4 were also rejected.

Sixty-seven bones were analyzed from the different areas in the cave. All were treated with 1N HCl, and an acid insoluble fraction was identified in 43 samples. This fraction was then isolated, and 25 samples were shown to produce a pure collagen infrared spectrum. The weight percentage of insoluble collagen ranged from 0.02% to 1.6%. The infrared splitting factor (IRSF) values of 4 samples were within 2.6-2.9, i.e., the IRSF values of fresh bones (29), while most of the samples had an IRSF value between 2.9 and 3.3. In some of the collagen spectra the presence of humic acid was detected; therefore, after whole pretreatment, the collagen was again characterized by infrared spectroscopy before target preparation for AMS dating (30).

Radiocarbon Analysis

A total of 27 samples were analyzed for their ^{14}C contents. They were selected based on the quality of context and material preservation. Of these, ten pretreated samples were separated into two parts and were prepared separately as duplicate analyses. Three samples (BA 95098, 95057a, 95057b) (12) were analyzed during the 1990s excavations when pre-screening procedures were not used (Table 1). Table 3 lists the 40 radiocarbon dates according to excavation square, and within each square the samples are arranged according to increasing stratigraphic depth. The duplicate analyses are also listed. The uncalibrated and calibrated ages are shown. All the radiocarbon dates were calibrated with OxCal 3.10 by Bronk-Ramsey 2005 (31, 32).

The reproducibility of the duplicate measurement analyses (Fig.3) shows that the data distribution based on the analytical uncertainty follows a normal distribution. This shows there is no bias between the measurements. There is no consistent difference between charcoal and bone samples from the same depth or level. In square T9, near the western cave wall, the ages are similar and show no trend with depth.

Figure 4 shows a plot of the calibrated ages obtained in each excavation square, and within each square the samples are arranged according to increasing depth. This shows that the upper part of each section contains sediments from around 13,800-14,600 cal BP. Older sediments were found close to the base of the sections in squares T1 D and E, as well as in squares T10-12. Most of these sediments are from around 16,400-18,000 cal BP. A major exception is a bone sample which was just above bedrock in T1 that gave an age of 21,000 cal BP.

Discussion

In each stratigraphic section from which samples were analyzed, the ages increase with increasing stratigraphic depth, with two exceptions. The dates show that the cave was occupied from around 18,000 to 14,000 cal BP (Table 3). There were some periods from which no dates were obtained. This may be due to the sample distribution or because during these periods very little sediment may have accumulated.

The mineralogical and micromorphological analyses of the sediments both indicate that ash calcite was a major component of almost all samples, implying that they were produced mainly during periods of human occupations. Another unusual anthropogenic activity is evidenced by the clay-rich sediment formed into lenticular bands that must have been brought into the cave by humans and functioned as prepared surfaces (Fig. S2). The clay may have been red colored initially or became red due to heating. Infrared analysis shows that some of these sediments were heated to temperatures between 400 and 500ºC (28).

Snail shells found in the cave sediments were analyzed and almost all were found to be composed entirely of aragonite. As aragonite is less stable than calcite, its presence indicates that the preservation conditions were generally good for ash and bones (33). Calcite however buffers the ground water to above pH 8, and this is often not conducive to the preservation of charred materials. In fact, the pre-screening showed that the charcoal was generally poorly preserved, especially in the eastern part of the cave, which today, at least, is much wetter than the western part (24). We also note that less than half the bones contained acid insoluble collagen. This, too, points to relatively poor preservation conditions for organic matter. Bearing this in mind, we assume that the consistent dates obtained can be attributed to the rigorous pre-screening procedures. We did not analyze the radiocarbon contents of any of the samples that were rejected during the pre-screening.

The distribution of the dates in the 70-80 cm of the upper part of the ash and red clay deposits reflect a more or less undisturbed accumulation as the series of radiocarbon dates demonstrate an increasingly older age with depth (Fig. 4). This is less clear in the area where most of the potsherds were found in Square T1.

During the 2004 excavation a sherd was found in sub-layer 3E at 255 cm below datum and close (some 40-50 cm) to where the original cluster of reconstructable potsherds were uncovered during the previous excavations. The location is shown in Fig. 1. The deposits in T1 between the large boulder and the northern section slope toward the northern wall of the cave and in addition were somewhat disturbed. We note that the two samples (RTT 5110 and RTT 5108) that are clearly out of the overall stratigraphic order are from this location.

The calibrated ages for sediments associated with the cluster of the pottery in T1 are from 13,580 to 16,950 cal BP with two standard deviations (SD) (RTB 5110, 5107, 5108, 5109 and 5114) (Table3). The sherd that was found in Square T11 is underlain and overlain by sediments that date between 17,150 and 18,600 cal BP with 2 SD (RTB 5465, 5463, 5466, 5464 and 5470). We note that a charcoal fragment from sub-layer 3E that was located just above the cluster of sherds during the previous excavation was dated to 13,680±70, or 15,850-16,700 cal BP (7) (BA95058, see Table 1). A fragment of the pot that was dated earlier produced a date of 14,390±230 calibrated as 15,450-18,050 with 2 SD (BA95057b, Table 1.). Bearing in mind that all the samples dated were from a ten centimeter thick sediment sequence that was rather disturbed, we conclude that the lower limit for the age of the ceramics is around

15,000 cal BP. The upper limit is based on the fragment found in square T11 that is more firmly dated to 18,300 cal BP.

Dates as early as 16,000 to 17,000 cal BP have been conjectured for the earliest pottery in East Asia, such as at the Xianrendong and Diaotonghuan sites in Jiangxi Province, but these could not be confirmed due to ambiguities in the stratigraphic sequences of these sites (8, 20). Our work in dating Yuchanyan Cave differs from previously dated early pottery sites in China in that it is based on high-precision dating the entire sequence of the deposits, and by doing this with small sampling intervals of only a few centimeters in the areas close to where potsherds were excavated. The results obtained allow us to securely date the pottery in Yuchanyan Cave to as early as 17,500 to 18,300cal BP (one standard deviation). These dates precede by thousand ^{14}C years the earliest date of the Incipient Jomon (NUTA-6510 13780±170 ^{14}C year BP) (34) 16700-16100 ±1SD, and 17050-15850 cal BP 2SD) pottery in the Japanese archipelago (8, 35, 36). This supports the proposal made in the past that pottery making by foragers began in south China.

Materials and Methods

Pre-screening in the field

In the field, samples from well defined contexts (for example ash lenses) were collected with the associated sediments. All charcoal pieces were collected separately, placed in aluminum foil, and dried before closing. For the bones, preliminary tests were conducted on-site by dissolving a small bone fragment in 1N HCl and then determining if a light insoluble fraction was preserved. The light insoluble fraction indicates, but does not prove, that insoluble collagen is preserved. As only about half the bones did have an insoluble fraction, we collected many more samples for an extensive pre-screening in the laboratory.

Prescreening in the laboratory

All the samples that were selected in the field based on context and size for radiocarbon dating were subjected to further pre-screening procedures in order to determine the state of preservation and finally their suitability for dating based on the quality parameters defined in (30).

Sixty four bones from squares T1, T4, T5, T9, T11, T12, T14 and T15 were initially checked in the laboratory for mineral crystallinity based on their splitting factor (37). The splitting factors ranged from 2.6 to 3.0, which is close to the value of 2.7±0.2 for modern bone (29). Only one sample had a splitting factor as high as 4. The HCl insoluble fraction was then quantitatively extracted and used to determine if any collagen was present based on infrared spectroscopy. The FTIR spectra of the 1N HCl insoluble fractions indicated that 23 samples showed good preservation of collagen as indicated by the 1645, 1545 and 1450 cm^{-1} Amide I and II and proline peaks respectively. In some of the collagen spectra the presence of collagen and/or humic acid was detected. Therefore after the entire pretreatment procedure, the collagen was again characterized by infrared spectroscopy to ensure that it was pure (30) before target preparation for AMS dating.

Many charcoal samples were collected and pre-screened in the laboratory before and after acid and alkali treatment using Raman micro-spectroscopy to assess humic acid contamination (30, 38) removal, infrared spectroscopy to assess clay contamination (30) and loss of weight. The latter proves to be a good indicator of charcoal preservation (24) and in practice determines the yield of clean charcoal and hence whether or not the sample can be dated. Only samples that were well preserved and free of detectable contaminants were dated.

Bone and charcoal pretreatment for radiocarbon

Sample pretreatment for bone and charcoal was performed at the Weizmann Institute according to the procedure presented in (30). The cleaning procedure for the collagen samples chosen for dating was based on the acid- alkali- acid (AAA) technique (39). The bone (2 to 4 g) was ground to powder and homogenized. Ten to 20 ml of 1N HCl were added and after 30 minutes the sample was centrifuged for 3 min at 3000 rpm. The supernatant was removed and the pellet was washed with distilled water (DW) to pH 7. The pellet was re-suspended in 7ml of 0.1 % NaOH for 15 minutes and centrifuged again for 7 minutes at 3000 rpm. The supernatant was removed and the pellet was washed with DW to pH 7. The atmospheric CO_2 adsorbed during the alkali treatment was removed by adding 7 ml of 1N HCl for 30 min. and washing the pellet until the supernatant reached pH 3. A few milliliters of solution were left over the pellet.

Gelatinization was achieved by heating the pellet in acid solution pH 3 to 70ºC for 20 hours (40). The solution was then filtered through a polyethylene filter (Eezi-filter^{TM}) and then by superfiltration (Vivaspin 20). The filtrate was lyophilized (Heto LyoLab 3000) to produce pure dry collagen(41). The quality of the collagen was checked again using infrared spectroscopy.

Charcoal Purification

The cleaning procedure was based on the AAA procedure (39), except that after each step the pellets were dried at 60ºC, weighed, and a few milligrams were taken for infrared and Raman analyses. The alkaline step was repeated between two to three times depending on the solution color, and in the last step after adding the 1N HCl, the solution was placed on a hot plate and heated slowly to 80ºC for an hour, centrifuged, and the pellet was washed with DW to pH 7 and dried at 60ºC.

Monitoring the removal of humic acids from the charcoal samples by Raman spectroscopy is based on the fact that humic acids tend to fluoresce strongly (42). Measurements were made using a Raman Imaging Microscope (Renishaw) through a 50× lens. The excitation at 632 nm was produced by a 25 mw He/Ne laser. Each homogenized sample was measured 10 times at different places, and the spectra were averaged. The spectral resolution was 4 cm^{-1} and the range analyzed was1200-2000 cm^{-1}. For details of the method see (38).

Bone and charcoal samples indicated the highest preservation and provided enough material for the accelerator mass spectrometry measurement.

Target preparation and ^{14}C measurement

The carbon content of the samples was analyzed by Elemental Analyzer – ELEMENTAR, vario EL, made in Germany. Samples were weighed according to their carbon contents and sealed with copper oxide and silver in quartz tubes under vacuum system. The combustion temperature was 850°. The CO_2 from the tubes was purified and transferred into the gas container separately. The reduction from CO_2 to graphite was performed with H_2/Fe in a new vacuum line. The new system has two graphitization lines, each line has 10 reactors. Fe catalyst is cleaned and activated under 450° C with O_2 and H_2 separately before reduction (43). The graphite was formed at 540° C. Magnesium perchlorate is used to trap water (44), and it was replaced for every new sample.

The AMS radiocarbon measurements were carried out on a NEC 1.5SDH-1 0.5MV Pelletron with 40-sample MC-SNICS ion source. The accuracy of this system is better than 0.4% and the machine background is lower than 0.03pMC.

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Figure Legends

Figure 1. Location of Yuchanyan Cave in China (inset) and excavation grid showing locations of ceramics.

Figure 2. Photograph of the section in square T11 showing the calcitic ash lenses and reddish clay-rich lenses. One of the ceramic sherds was found embedded in this sequence. Its location is marked with O. Scale bar: 20cms.

Figure 3: Plot of the duplicate measurements showing the distribution of the data and the analytical reproducibility. The linear interpolation line with the intercept =0 and the correlation coefficient are shown in the plot. The data are reported in table 2.

Figure 4: Age distribution of the samples analysed from Yuchanyan Cave. The samples are ordered according to stratigraphic depth following Table 3.

Table Legends

Table 1. Uncalibrated and calibrated radiocarbon dates of the samples analyzed after the excavations in 1993 and 1995 (Yuan 2002).

Table 2: Pre-screening results for bones and charcoal from different excavation squares in the cave.

Table 3. Uncalibrated and calibrated radiocarbon dates of all the samples analyzed. The samples are ordered by stratigraphic depth. The results from the western section (T9, T1, T10-T12) are followed by those from the eastern section (T5). Note that there is a distance of about 5m between the two areas in the cave.

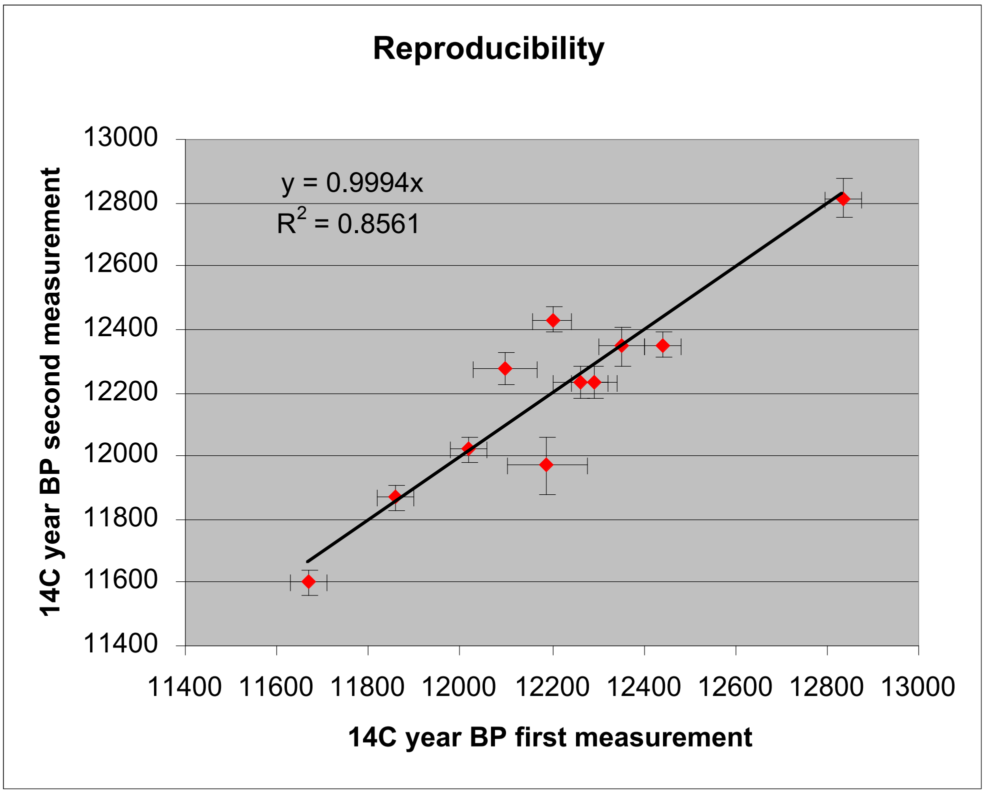

Figure 3: Age distribution of the samples analysed from Yuchanyan Cave. The samples are ordered according to stratigraphic depth following Table 3.

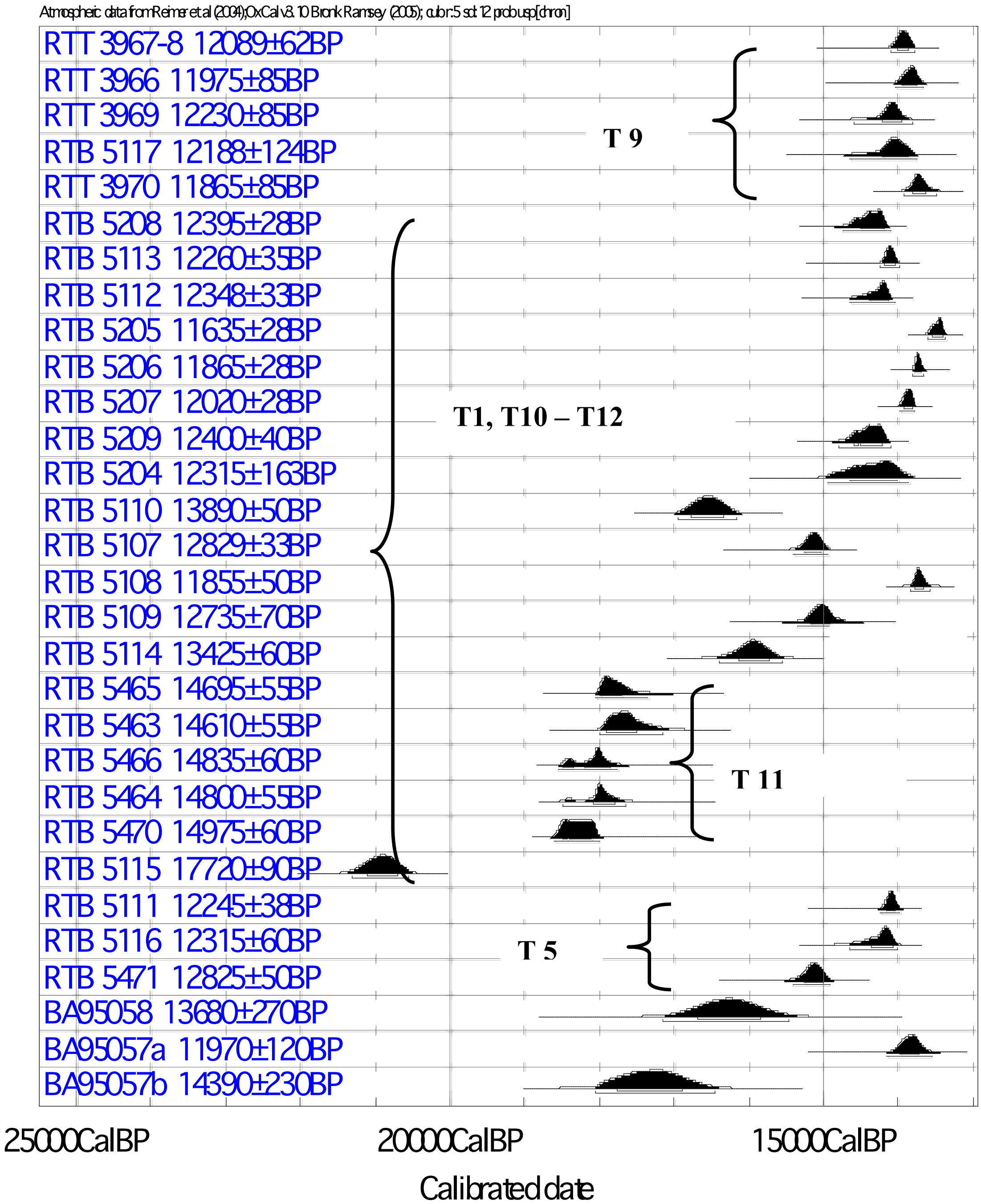
Atmospheric data from Reimer et al (2004);OxCal v3.10 Bronk Ramsey (2005); cub r:5 sd:12 prob usp[chron]
RTT 3967-8 12089±62BP
RTT 3966 11975±85BP
RTT 3969 12230±85BP
RTB 5117 12188±124BP
RTT 3970 11865±85BP
RTB 5208 12395±28BP
RTB 5113 12260±35BP
RTB 5112 12348±33BP
RTB 5205 11635±28BP
RTB 5206 11865±28BP
RTB 5207 12020±28BP
RTB 5209 12400±40BP
RTB 5204 12315±163BP
RTB 5110 13890±50BP
RTB 5107 12829±33BP
RTB 5108 11855±50BP
RTB 5109 12735±70BP
RTB 5114 13425±60BP
RTB 5465 14695±55BP
RTB 5463 14610±55BP
RTB 5466 14835±60BP
RTB 5464 14800±55BP
RTB 5470 14975±60BP
RTB 5115 17720±90BP
RTB 5111 12245±38BP
RTB 5116 12315±60BP
RTB 5471 12825±50BP
BA95058 13680±270BP
BA95057a 11970±120BP
BA95057b 14390±230BP
T 9
T1, T10 – T12
T 11
T 5
25000CalBP
20000CalBP
15000CalBP
Calibrated date

Table 1. Uncalibrated and calibrated radiocarbon dates of the samples analyzed after the excavations in 1993 and 1995 (Yuan 2002).

PKU lab Number			^{14}C age±1σ year BP	Calibrated age ±1σ year BP	Calibrated age ±2σ year BP
BA95058	Charcoal	T1, layer: 3E	13680 ± 270	16700 - 15850	17150 - 15450
BA95057a	Humic substances from Potsherds	T1, layer: 3H	11970 ± 120	13970 - 13720	14150 - 13550
BA95057b	Potsherds residue	T1, layer: 3H	14390 ± 230	17750 - 16900	18050 - 16450

Table 2: Pre-screening results for bones and charcoal from different excavation squares in the cave.

Excavation square	Bones		Charcoal	
	No. of samples analyzed	No. samples with pure collagen suitable for dating	No. of samples analyzed	No. of well preserved samples suitable for dating
T9	2	1	(4)	(2)
T1 Sub-squares D and E	6	2	12	10
T10				
T11	21	10	18	5
T12	11	8	8	6
T4	12	3	21	4
T5	12	2	12	6
Totals	64	26	75	33

Table 3. Uncalibrated and calibrated radiocarbon dates of all the samples analyzed. The samples are ordered by stratigraphic depth. The results from the western section (T9, T1, T10-T12) are followed by those from the eastern section (T5). Note that there is a distance of about 5m between the two areas in the cave.

Weizmann Institute Number	PKU lab Number			^{14}C age±1σ year BP	Calibrated age ±1σ year BP	Calibrated age ±2σ year BP
RTT 3967 RTT 3968	 **Average**	charcoal	T9, west section, 129cm	12190 ± 85 11970 ± 90 **12089 ± 62**	14020 - 13850	14090 - 13790
RTT 3966		charcoal	T9, west section, 135cm	11975 ± 85	13940-13750	14030-13670
RTT 3969		charcoal	T9, west section, 190cm	12230 ± 85	14210-13960	14600-13800
RTB 5117 RTB 5117	BA05429a BA05429b **Average**	bone	T9, west section, 191m	12100 ± 70 12275 ± 50 **12188 ± 124**	14210 - 13850	14650 - 13750
RTT 3970		charcoal	T9, west section, 194cm	11865 ± 85	13820 - 13630	13920 – 13480
RTB 5208 RTB 5208	BA05898-1 BA05898-2 **Average**	bone	T10a, 3A, 195cm	12440 ± 40 12350 ± 40 **12395 ± 28**	14490 - 14190	14750 – 14100
RTB 5113 RTB 5113	BA05425a BA05425b **Average**	charcoal	T1, south, 198cm	12290 ± 50 12230 ± 50 **12260 ± 35**	14180 - 14050	14250 – 13990
RTB 5112 RTB 5112	BA05424a BA05424b **Average**	charcoal	T1, south, 204cm	12360 ± 50 12345 ± 60 **12348 ± 33**	14380 - 14130	14650 – 14050
RTB 5205 RTB 5205	BA05895-1 BA05895-2 **Average**	charcoal	T11a, 3A IV, 217cm	11670 ± 40 11600 ± 40 **11635 ± 28**	13540 - 13410	13620 – 13370
RTB 5206 RTB 5206	BA05896-1 BA05896-2 **Average**	charcoal	T10a, 3A, 219cm	11860 ± 40 11870 ± 40 11865 ± 28	13780 - 13700	13820 – 13650
RTB 5207 RTB 5207	BA05897-1 BA05897-2 Average	charcoal	T1c, 3BIII, 228cm	12020 ± 40 12020 ± 40 **12020 ± 28**	13930 - 13810	13980 – 13780
RTB 5209	BA05899	bone	T10c, 3B III, 230cm	12400 ± 40	14580(6.7%)14530 14500(61.5%)14200	14800 -14100
RTB 5204 RTB 5204	BA05894-1 BA05894-2 **Average**	charcoal	T11a, 3C, 236cm	12200 ± 40 12430 ± 40 **12315 ± 163**	14650 - 14000	14950 – 13850
RTB 5110	BA05422	charcoal	T1D-c, layer: 3E, 251cm	13890 ± 50	16760 - 16340	16950 – 16150
RTB 5107 RTB 5107	BA05419a BA05419b	charcoal	T1E, layer: 3E, 251cm	12835 ± 40 12815 ± 60	15250 - 15020	15400 – 14940

	Average			**12829 ± 33**		
RTB 5108	BA05420	charcoal	T1E, layer: 3E 254cm	11855 ± 50	13790 - 13670	13840 – 13580
RTB 5109	BA05421	charcoal	T1A, layer: 3E, 255cm	12735 ± 70	15170 - 14910	15350 -14700
RTB 5114	BA05426	bone	T1E, layer: 3E 253-258cm	13425 ± 70	16140 - 15740	16400 – 15550
RTB 5465	BA06865	bone	T11a, layer: 3FH, 252cm	14695 ± 55	17990 - 17700	18050 – 17350
RTB 5463	BA06863	charcoal	T11c, layer: 3H, 255cm	14610 ± 55	17900 - 17510	18000 – 17150
RTB 5466	BA06866	bone	T11c, layer: 3H, 257cm	14835 ± 60	18500(14.1%)18350 18200(54.1%)17850	18550-17750
RTB 5464	BA06864	charcoal	T11c, layer: 3H, 260cm	14800 ± 55	18080 - 17800	18500 – 17650
RTB 5470	BA06867	Charcoal	T12a, layer: 3H, 260 cm	14795 ± 60	18500(13.3%)18420 18390(54.9%)18100	18600 – 18000
RTB 5115	BA05427	Bone	T1E, layer: 3I, 260-264cm	17720 ± 90	21110 - 20700	21300 – 20550
RTB 5111 RTB 5111	BA05423a BA05423b **Average**	charcoal	T5, east, 222cm	12260 ± 60 12235 ± 50 **12245 ± 38**	14160 - 14040	14230 – 13980
RTB 5116	BA05428	bone	T5, east, 229cm	12315 ± 60	14370 - 14070	14650 – 14000
RTB 5471	BA06868	charcoal	T5, 305-314cm	12825 ± 50	15250 -15010	15420 – 14920